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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER ENVPREDRSCHFAC Technical Note No. 16
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
A Fine Mesh Sea-Level Pressure Analysis Scheme Incorporating Effects of Elevation and Terrain

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
L. Robin Brody

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Environmental Prediction Research Facility
Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Air Systems Command
Department of the Navy
Washington, D.C. 20361

12. REPORT DATE
April 1974

13. NUMBER OF PAGES
31

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)
Naval Air Systems Command
Department of the Navy
Washington, D.C. 20361

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Computer model
Fine-mesh sea-level pressure analysis
Orographically induced wind system
Mediterranean area
Pressure gradients
DMSP satellite data
Regional winds

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
There has long been a need for a computer analysis scheme to accurately depict the orographically induced wind systems of the Mediterranean basin. This document describes a fine mesh sea-level pressure analysis scheme for the Mediterranean area with a grid length of approximately 50 n mi. This analysis scheme was developed under a contract awarded to Meteorology International, Inc. and is currently in full operational use at Fleet Numerical Weather Central.

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S/N 0102-014-6601

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20. (continued)

The analysis scheme is an adaptation of the Fields by Information Blending methodology, Sea-Level Pressure version (FIB/SLP) for the northern hemisphere. The effect of orography is included in two ways. First, weights of individual pressure reports are reduced depending upon the elevation of each report, with a final addition of variance associated with the height above sea level of the closest grid point. Secondly, topographical range information between grid points is used to dissociate pressure information across a mountain barrier by affecting the weights of spreading parameters. The effect of this dissociation is to permit realistic analysis of extremely tight pressure gradients.

To test the accuracy of the fine mesh FIB/SLP, a case study including high resolution satellite pictures from the Defense Meteorological Satellite Program (DMSP) system was compiled. This case study, which includes two of the most significant regional winds of the Mediterranean, showed that the analysis scheme is capable of distinguishing between similar pressure patterns which produce considerably different wind regimes.

AN (1) AD- 779 005
FG (2) 040200
CI (3) (U)
CA (5) ENVIRONMENTAL PREDICTION RESEARCH FACILITY (NAVY)
MONTEREY CALIF
TI (6) A Fine Mesh Sea-Level Pressure Analysis Scheme
Incorporating Effects of Elevation and Terrain.
TC (8) (U)
AU (10) Brody,L. Robin
RD (11) Apr 1974
PG (12) 35p
RS (14) ENVPREDRSCHF-tech-note-16
RC (20) Unclassified report
DE (23) *Weather forecasting, *Wind, *Mediterranean Sea,
Barometric pressure, Elevation, Terrain, Computerized
simulation, Orography, Numerical analysis, Cyclones,
Correlation techniques
DC (24) (U)
ID (25) Spaceborne photography
IC (26) (U)
AB (27) The document describes a fine mesh sea-level pressure
analysis scheme for the Mediterranean area with a grid
length of approximately 50 n mi. The analysis scheme is
an adaptation of the Fields by Information Blending
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wind regimes. (Modified author abstract)
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Technical Note No. 16

A FINE MESH SEA-LEVEL PRESSURE ANALYSIS SCHEME INCORPORATING EFFECTS OF ELEVATION AND TERRAIN

by

L. ROBIN BRODY

APRIL 1974

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CONTENTS

A FINE MESH SEA-LEVEL PRESSURE ANALYSIS SCHEME INCORPORATING EFFECTS OF ELEVATION AND TERRAIN

by

L. Robin Brody

I. INTRODUCTION

The Environmental Prediction Research Facility (EPRF) has developed a fine mesh sea-level pressure analysis scheme for the Mediterranean region. This analysis scheme, which was developed under a contract awarded to Meteorology International Inc., was required because of the need to accurately depict the subsynoptic-scale weather phenomena which occur in the Mediterranean basin.

The purpose of this paper is to describe the pertinent procedures of the analysis scheme and its capabilities of distinguishing between similar pressure patterns which produce considerably different wind regimes over the Mediterranean. A case study which includes two of the most important regional winds of the Mediterranean basin is used to highlight the capabilities. Both the observed winds and inferences made from the high-resolution Defense Meteorological Satellite Program (DMSP) system are used for verification purposes.

2. ANALYSIS SCHEME

The procedure used for this fine mesh sea-level pressure analysis is an adaptation of the Fields by Information Blending methodology/Sea-Level Pressure (FIB/SLP) version for the northern hemisphere developed by Holl and Mendenhall (1971). The FIB technique treats information as a metered commodity. It is based entirely on rules for adding independent information in the form of observations of the parameter to be analyzed, and information related to integral and differential properties of the parameter. FIB/SLP assimilates (1) pressure values, (2) pressure-gradient values derived from winds, and (3) Laplacian values for pressure. A complete mathematical description of the FIB/SLP scheme is found in Holl and Mendenhall (1971).

As is shown in Figure 1, the Mediterranean basin is surrounded by complex topographical features. For this reason the hemispheric FIB/SLP scheme was modified so as to be able to depict the pressure of this region. The remainder of this section will deal with the specific modifications and the reasons they were made. A mathematical description of the fine mesh FIB/SLP version for the Mediterranean region (FIB/SLP-MED) is found in Project Performance Report, Meteorology International Project M-179, 12 October 1972.

2.1 AREAL COVERAGE

Because of computer limitations, the FIB/SLP-MED version is only computed for a limited sub-set on the Fleet Numerical Weather Central (FNWC) hemispheric grid. The initial program was written for any rectangular grid of up to 125 x 125 grid points but, for the Mediterranean scheme, only 63 x 63 grid points are used. The approximate corner-point locations (clockwise from upper left) are 57N 38W, 52N 65E, 16N 32E, and 18N 7W. This area is shown in Figure 2. The area was

extended southward into North Africa to allow the FIB/SLP-MED scheme to analyze developing North African depressions. These cyclones at times move into the Mediterranean with explosive deepening (Reiter, 1971).

2.2 GRID SPACING

The grid spacing for the FIB/SLP-MED is 0.25 of the standard FNWC grid spacing; in comparison the hemispheric FIB/SLP has a spacing of 0.50. This grid length of approximately 50 n mi is necessary, as will be shown in a later section, in order that the subsynoptic scale pressure systems which occur within the Mediterranean basin may be correctly depicted. A sample of the grid spacing is shown in Figure 2.

2.3 BOUNDARIES AND INITIALIZATION

Because of the limited area of the FIB/SLP-MED grid, it was necessary to allow for extrapolation from outside the grid for the kinematical extrapolation of the first guess analysis. This was done by using the 6-hour-old hemispheric FIB/SLP analysis covering an area 300 n mi (6 fine-mesh grid lengths) beyond the limited area grid. This expanded field and the 6-hour-old FIB/SLP-MED field are then combined with 100% hemispheric FIB/SLP weight outside the border and 20% FIB/SLP-MED (80% hemispheric FIB/SLP) weight at the border, increasing to 100% FIB/SLP-MED weight 4 grid lengths and more inside. In this way, extrapolation is performed right up to the border with information also being brought in from the surrounding hemispheric grid points.

2.4 ELEVATION AND TERRAIN

The effects of elevation and terrain are incorporated in the FIB/SLP-MED to a higher degree than in the case of the hemispheric FIB/SLP. First, a method of reducing the weights of pressure reports for high elevation stations described by Holl and Mendenhall (1971) has been incorporated. Next, a procedure is used to confine the total collected weight of the

observed pressure observations within a grid module. This method adds an extra variance to the collection of pressure reports at each grid point associated with the reduction to sea level from the modal height of the grid module. The effect of this procedure is to reduce the weight of the pressure values at high elevation grid points.

The second method for incorporating orography deals with dissociation of pressure information across a mountain barrier. The elevation data at 10-minute latitude and longitude intersections obtained from a topographic data tape developed at FNWC was used to determine the elevation range between the grid points of the fine mesh grid. This range data in the form of standard deviations is used to affect the weights of the spreading parameters (Holl and Mendenhall, 1971). As the range (standard-deviation) increases, the effect that a grid point has on its neighbors (described by the weights of the spreading parameters) decreases. In the case of the FIB/SLP-MED, the spreading parameters are derived from observed wind information and geostrophic vorticity. An example of dissociation of pressure across a mountain barrier is shown in Figure 3. This analysis shows a ridge of high pressure extending from west of the Bay of Biscay to north of the Alps while lower pressures exist to the south. The realistic depiction of the strong pressure gradient across the Alps in the vicinity of point A, is caused by the dissociation of pressure information across this mountain barrier.

3. EFFECTS OF OROGRAPHY ON THE PRESSURE PATTERNS OF THE MEDITERRANEAN BASIN

As has been described in paragraph 2.4, the FIB/SLP-MED scheme includes modifications which should help to correctly analyze changes in the pressure distribution associated with elevation and terrain. Following are descriptions of several situations when orography might be expected to modify the pressure patterns, and reasons why the FIB/SLP-MED scheme should correctly analyze these situations.

3.1 REDUCTION OF STATION PRESSURE TO SEA LEVEL

Errors in the reduction of station pressure to sea level can cause artificially strong pressure gradients in mountainous terrain. Since the Mediterranean is almost completely surrounded by mountains, it is important to prevent incorrect pressure reports in the immediate interior from affecting coastal pressure gradients. The FIB/SLP-MED scheme overcomes this problem by reducing the weights of pressure values at high level grid points and, therefore, their possible affect on surrounding coastal grid points.

3.2 AIR MASS DISCONTINUITIES

Topography can also have an effect on pressure gradients when cold air is banked up along one side of a mountain barrier. This type of pressure discontinuity, which can be extremely intense, is often observed over the North American continent during the winter; cold Arctic air moves southward east of the continental divide while warm Pacific air remains to the west. Over the Mediterranean basin, similar orographically induced "fronts" can be found along the Alps at the start of the mistral (see Reiter, 1971) and along the Dinaric Alps of western Yugoslavia at the onset of bora conditions. Figure 4 in the vicinity of Point A shows a case of cold air banked on the eastern side of the Dinaric Alps at the onset of a bora in

the Adriatic Sea. As explained in the previous section the capabilities of the FIB/SLP-MED scheme to dissociate pressure information across a mountain barrier has allowed the analysis scheme to display the strong pressure gradients associated with this orographically induced front.

3.3 TOPOGRAPHICALLY INDUCED CYCLOGENESIS

The occurrence of lee cyclogenesis in the region of the Alps (and other mountain ranges surrounding the Mediterranean) is another effect of topography on pressure gradient which must be considered. Due to the conservation of potential vorticity, a northerly flow across the Alps will cause cyclogenesis south of the Alps (Reiter, 1972). In addition, Godev (1971a, 1971b) shows that the effect of a curved orographic barrier is to cause decreasing atmospheric pressure on the concave side and increasing pressure on the convex side (independent of wind direction). Thus cyclogenesis can be expected south of the Alps (the concave side), and anticyclogenesis on the north slope of the Alps (the convex side). With both the potential vorticity and curved orographic barrier effects operating, extremely strong pressure gradients can be expected across the Alps.

Figure 5 shows a case of topographically induced cyclogenesis south of the Alps. A strong pressure gradient can be seen in the vicinity of Point A between the low and a ridge just north of the Alps. The ability of the FIB/SLP-MED scheme to dissociate pressure information across this mountain barrier allows the center of the low to be positioned near the southern boundary of the Alps and not farther to the south where it would affect the pressure analysis and, thus, the inferred winds over both the Gulf of Genoa and the Gulf of Venice.

4. VERIFICATION

To investigate the capabilities of the FIB/SLP-MED scheme in correctly depicting the orographically induced pressure patterns and gradients described in the previous sections, a case study covering the period 26 to 29 January 1973 was collated. Included in this period were two of the most important orographically induced wind systems of the Mediterranean basin. The first, the mistral, a combination fall wind and jet-effect wind, blows from the northwest into the Gulf of Lions and western Mediterranean from the Garonne-Carcassonne gap and the Rhone Valley (Air Ministry, 1962; and Reiter, 1972). The second wind is the bora of the Adriatic Sea. This is primarily a fall wind which blows from the northeast through the Trieste gap and over the Dinaric Alps (Air Ministry, 1962; and Meneely and Merritt, 1973).

Verification of the occurrence and areal domain of these two winds, as inferred from the analyzed pressure gradients, was accomplished by using both observed wind reports and deductions made from high resolution DMSP data. In the case of the mistral, a satellite picture should show mostly clear skies in the Gulf of Lions associated with the initial dryness of the cold air. Farther off shore, Meneely and Merritt (1973) have observed an increase of cloud cover with wispy leading edge bands. Another feature that can be observed, at times, from the DMSP pictures is a shear line which is found to exist on the western side of the mistral. USS FORRESTAL (see Reiter, 1971) has reported that this shear line is usually oriented from the northeast tip of Spain southeast to Minorca in the Balearic Islands, and at times is marked by clouds. This cloud line should be visible on the high resolution DMSP pictures. In the case of the bora, the foehn wall should be visible from the DMSP pictures over the crest of the Dinaric

Alps. Meneely and Merritt (1973) state, however, that the foehn wall is many times masked by higher clouds due to the close proximity of cyclonic disturbances to the south. This problem is minimized by using the DMSP IR pictures to locate areas free from these higher clouds.

4.1 26 JANUARY 1973

The FIB/SLP-MED analyses at both 0600 and 1200 GMT (Figures 6a and 6b) show as a significant feature the occurrence of a tight pressure gradient across the Dinaric Alps in the vicinity of Point A while at the same time a slack gradient is analyzed over the Adriatic Sea (Point B). Therefore, these analyses indicate that bora conditions have not advanced out over the water. This statement seems to be verified by the light winds reported at coastal stations surrounding the Adriatic Sea. A more positive verification of the lack of bora conditions over the Adriatic Sea is found on the DMSP pictures in Figures 7a and 7b for 1009 GMT. These pictures show that the foehn wall cloud usually found over the Dinaric Alps in the vicinity of point A during bora conditions is lacking. Most of the white area in the region of Figure 7a is snow cover. However, over the northern Adriatic Sea in the vicinity of point B, there is extensive low cloud cover (compare Figures 7a and 7b) which does not occur during bora conditions.

4.2 27 JANUARY 1973

The FIB/SLP-MED analysis for 1200 GMT, Figure 8, and DMSP pictures for 1136 GMT, Figures 9a and 9b, are shown only for continuity purposes. However, from Figure 8, cyclogenesis can be seen to be taking place in the Gulf of Genoa with relatively tight pressure gradient to the west as mistral conditions begin. The DMSP pictures show extensive cloudiness in this region indicating, on the other hand, that dry subsiding air characteristic of the mistral is not present.

4.3 28 JANUARY 1973

The FIB/SLP-MED analysis in Figure 10 for 1200 GMT shows that the cyclone which was developing on 27 January has rapidly deepened and moved southeastward into the central Mediterranean. To the west of the storm center, the tight pressure gradient which extends from southern France to North Africa indicates a well developed mistral. The DMSP pictures for 1122 GMT, seen in Figures 11a and 11b, show the clear area in the Gulf of Lions with wispy clouds evident to the south; a common condition during a strong mistral.

As has been discussed at the beginning of this section, shear lines are common features on the western edge of the mistral. From Figure 10, a sharp change in the pressure gradient is evident in the vicinity of Point A where a shear line might be expected. The wind reports in the Balearic Islands appear to substantiate this feature. On the DMSP pictures, the shear line appears in the vicinity of point A as a north-south line of low clouds intersecting Majorca. This is in close agreement with the FIB/SLP-MED analysis.

Another feature in the pressure pattern seen in Figure 10 is the large change in pressure gradient across the Alps. Because of the dissociation of pressure information across the Alps, which is considered in the analysis scheme, pressure gradients are shown to be strong over the Alps in the vicinity of Point B and weak over the Gulf of Genoa (Point C). Since the winds in the region of the Gulf of Genoa are relatively light, the FIB/SLP-MED has correctly analyzed this feature.

4.4 29 JANUARY 1973

On this final day of the case study, the FIB/SLP-MED analysis (Figure 12) shows that the intense cyclone has continued to move southeastward and by 1200 GMT 29 January was located near the southwest coast of Greece. The major feature to be verified is the bora condition likely to exist as a

result of the pressure gradient over the Adriatic Sea. This analysis is quite different from that of 26 January (Figure 6) when the strong pressure gradient occurred only across the Dinaric Alps with weak gradients over the water.

The observed coastal winds in Figure 12 confirm the likelihood of strong winds over the Adriatic Sea, and confirmation is given by the DMSP pictures for 1107 GMT (Figures 13a and 13b). As stated earlier, the foehn wall over the Dinaric Alps during bora conditions is sometimes obscured by higher clouds. In this case, the edge of the higher clouds extends northward to northern Albania (see Point A on Figure 13b). North of Point A, the foehn wall is evident with clear skies over the Adriatic Sea.

Finally, as on 28 January, the FIB/SLP-MED analysis for 29 January maintains a tight pressure gradient over the Alps in the vicinity of Point B (compare Figures 10 and 12). Again the slack pressure gradient to the south (Point C) is substantiated by the observed light winds.

5. CONCLUSIONS

As shown in section 4, the FIB/SLP-MED scheme demonstrates skill in correctly analyzing modifications in the pressure distribution associated with orography. In the case of cyclogenesis south of the Alps, the ability to dissociate pressure information across this mountain barrier allows pressure gradients (and thus inferred winds) to be correctly determined over the Gulf of Genoa. For the same reason, the FIB/SLP-MED scheme appears able to discriminate between cases when bora conditions extend from the Dinaric Alps out over the Adriatic Sea, and cases when strong pressure gradients and bora conditions are not found to the west of the Dinaric Alps. Finally, because of the closeness of the grid spacing, the FIB/SLP-MED scheme shows skill in locating the lateral boundaries of the mistral.

Because of this initial success of the FIB/SLP-MED analysis scheme, EPRF is currently developing a fine-mesh wind analysis scheme for the Mediterranean basin through a contract awarded to Meteorology International Inc.. For its first-guess field, this wind analysis scheme, which also employs the FIB techniques, uses winds derived from the corresponding FIB/SLP-MED analysis.

REFERENCES

Air Ministry, Meteorological Office, 1962: Weather in the Mediterranean, general meteorology. Vol. 1,London: Her Majesty's Stationery Office, 372 pp.

Godev, N., 1971a: The cyclogenetic properties of the Pacific coast: possible source of errors in numerical prediction. J. Atmos. Sci., 28, 968-972.

Godev, N., 1971b: Anticyclonic activity over south Europe and its relationship to orography. J. Appl. Meteor., 10, 1097-1102.

Holl, M.M., and B.R. Mendenhall, 1971: Fields by information blending sea-level pressure version. Fleet Numerical Weather Central, Technical Note No. 72-2, 65pp.

Meneely, J.M., and E.S. Merritt, 1973: Satellite observations of anomalous local wind events in the Mediterranean region. EPRF 51-0673-003, 129 pp.

Meteorology International Incorporated, 1972: Adaptation of an objective sea-level pressure analysis scheme to the Mediterranean region. Project Performance Report, MII, Project 17-179, 12 pp.

Reiter, E. R., 1971: Digest of selected weather problems of the Mediterranean. NAVWEARSCHFAC Tech. Paper No. 9-71.

Reiter, E.R. 1972: Atmospheric Transport Processes, Part 3: hydrodynamic tracers, AEC Critical Review Series, USAEC Report TID-25731.

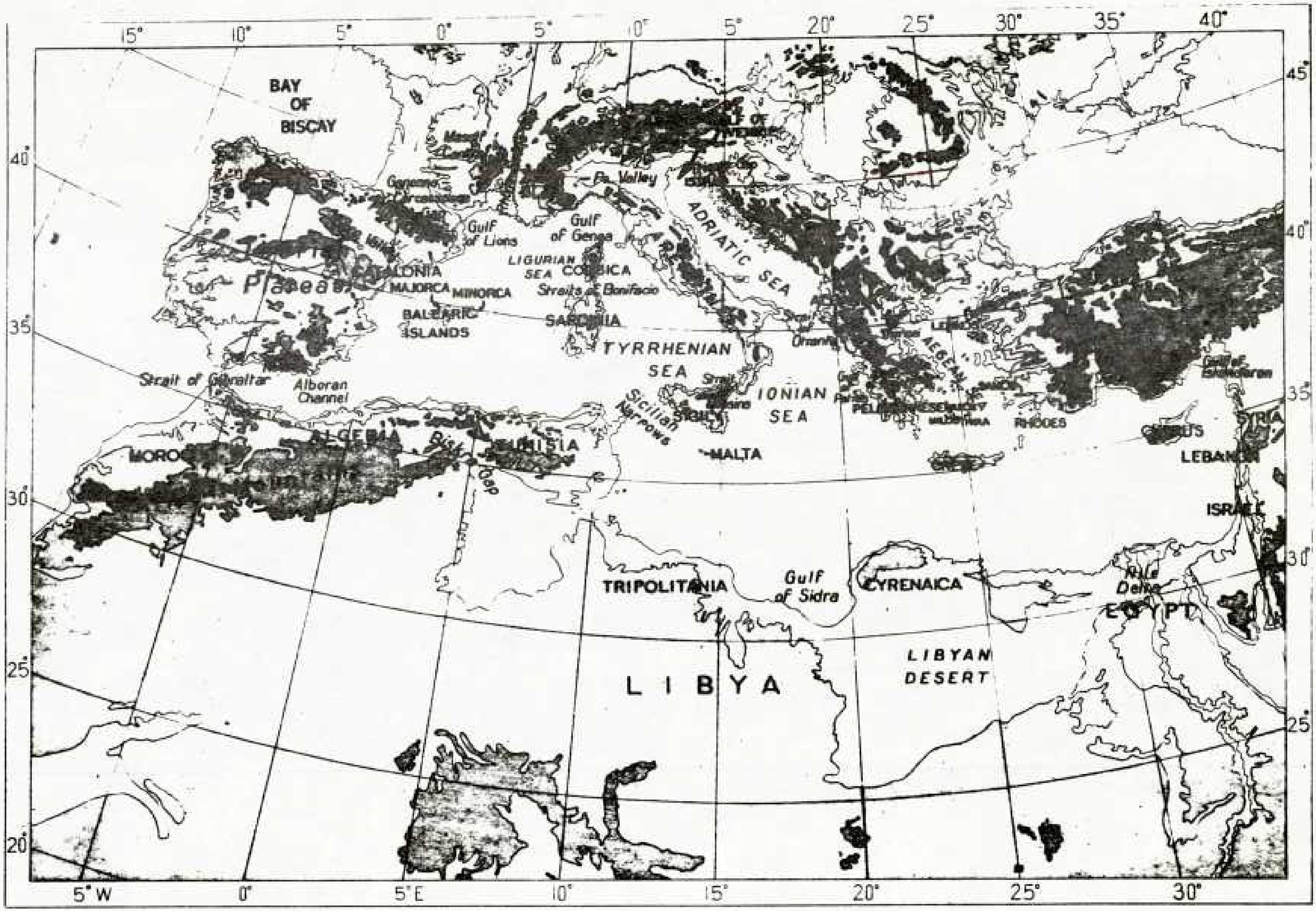

Figure 1. General locator map of the Mediterranean basin (Air Ministry, 1962).

Figure 2. FIB/SLP-MED areal coverage with sample of grid spacing.

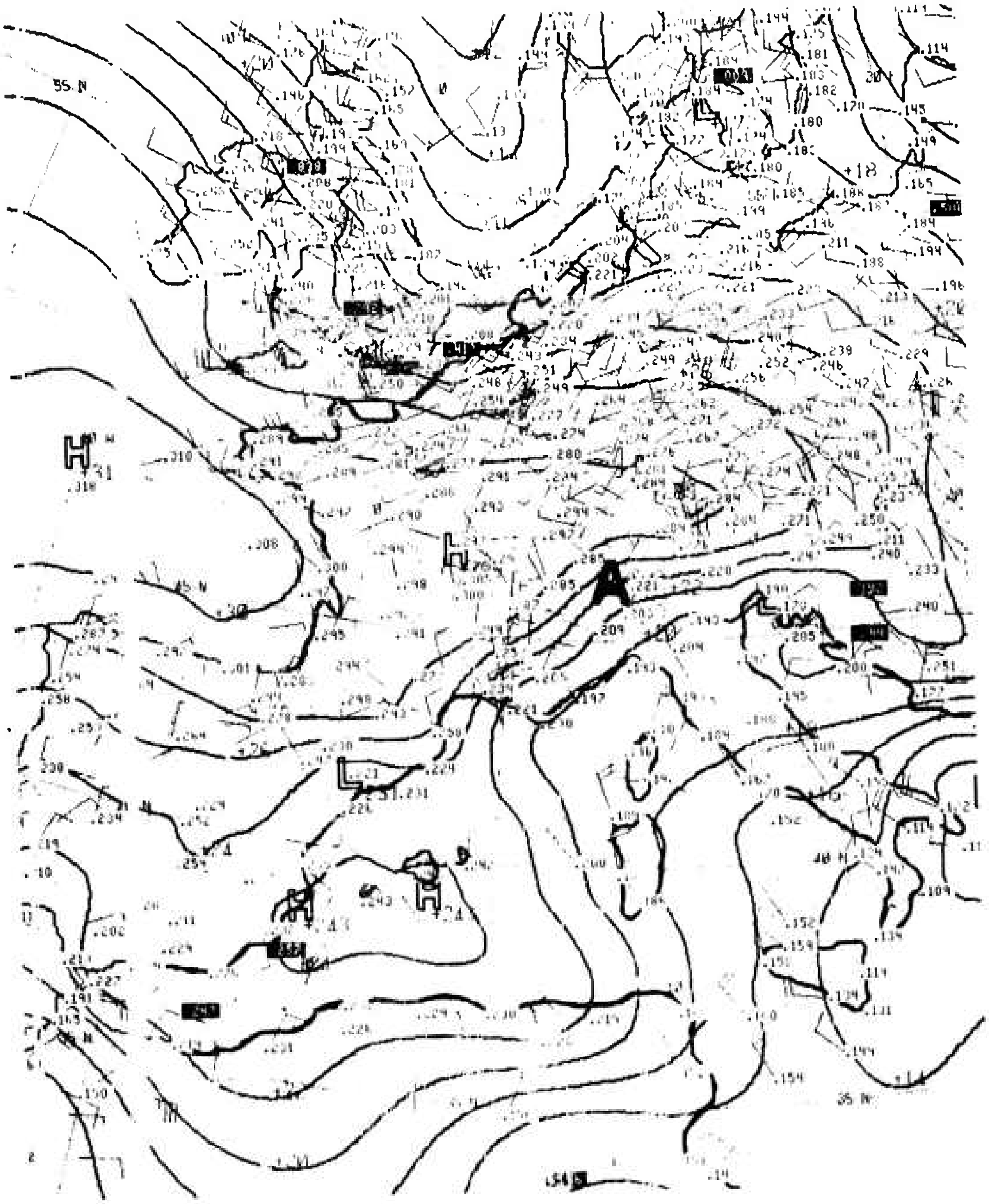

Figure 3. FIB/SLP-MED analysis, 1800 GMT, 22 October 1973.

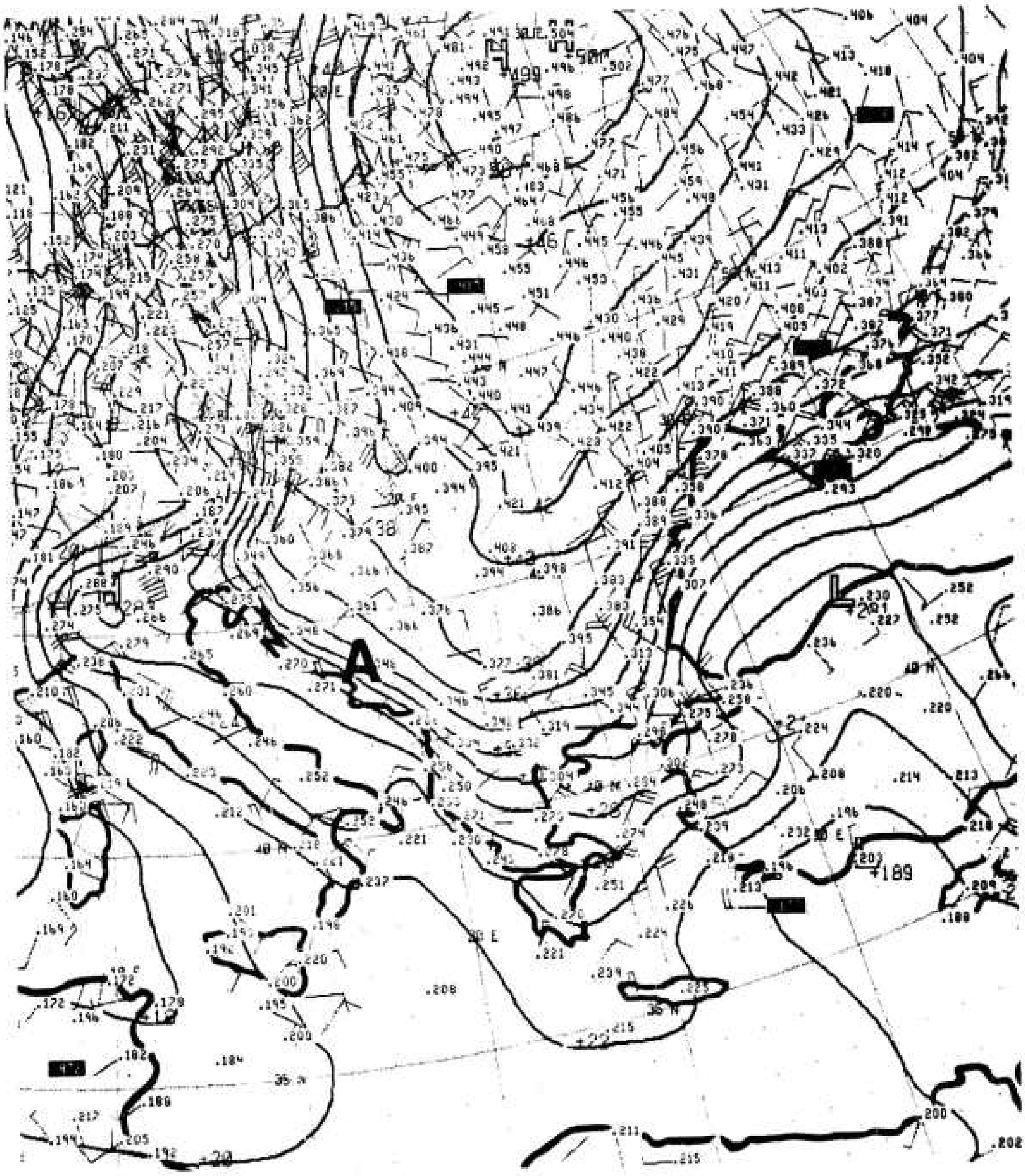

Figure 4. FIB/SLP-MED analysis, 0600 GMT, 28 December 1972.

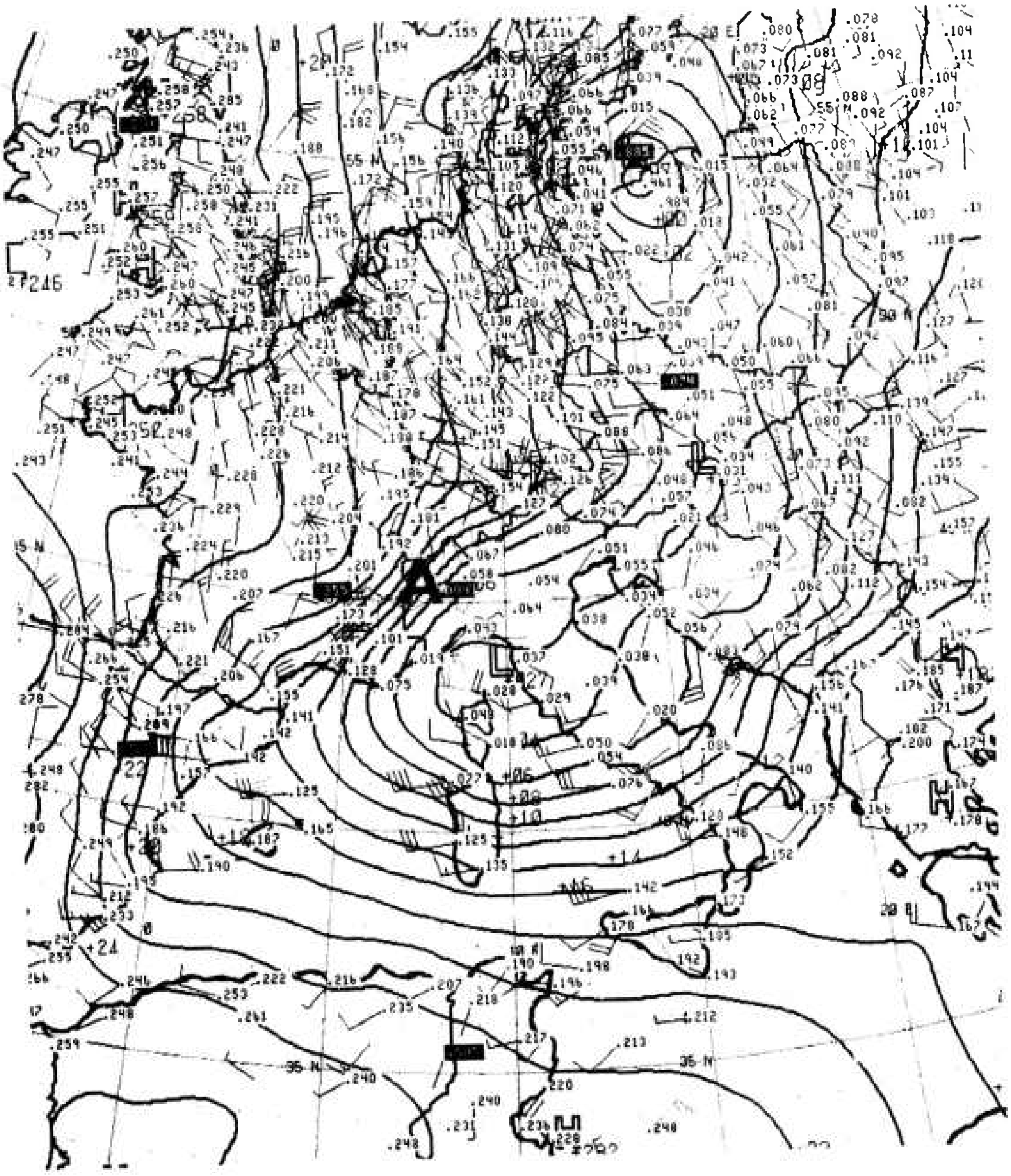

Figure 5. FIB/SLP-MED analysis, 1800 GMT, 29 November 1973.

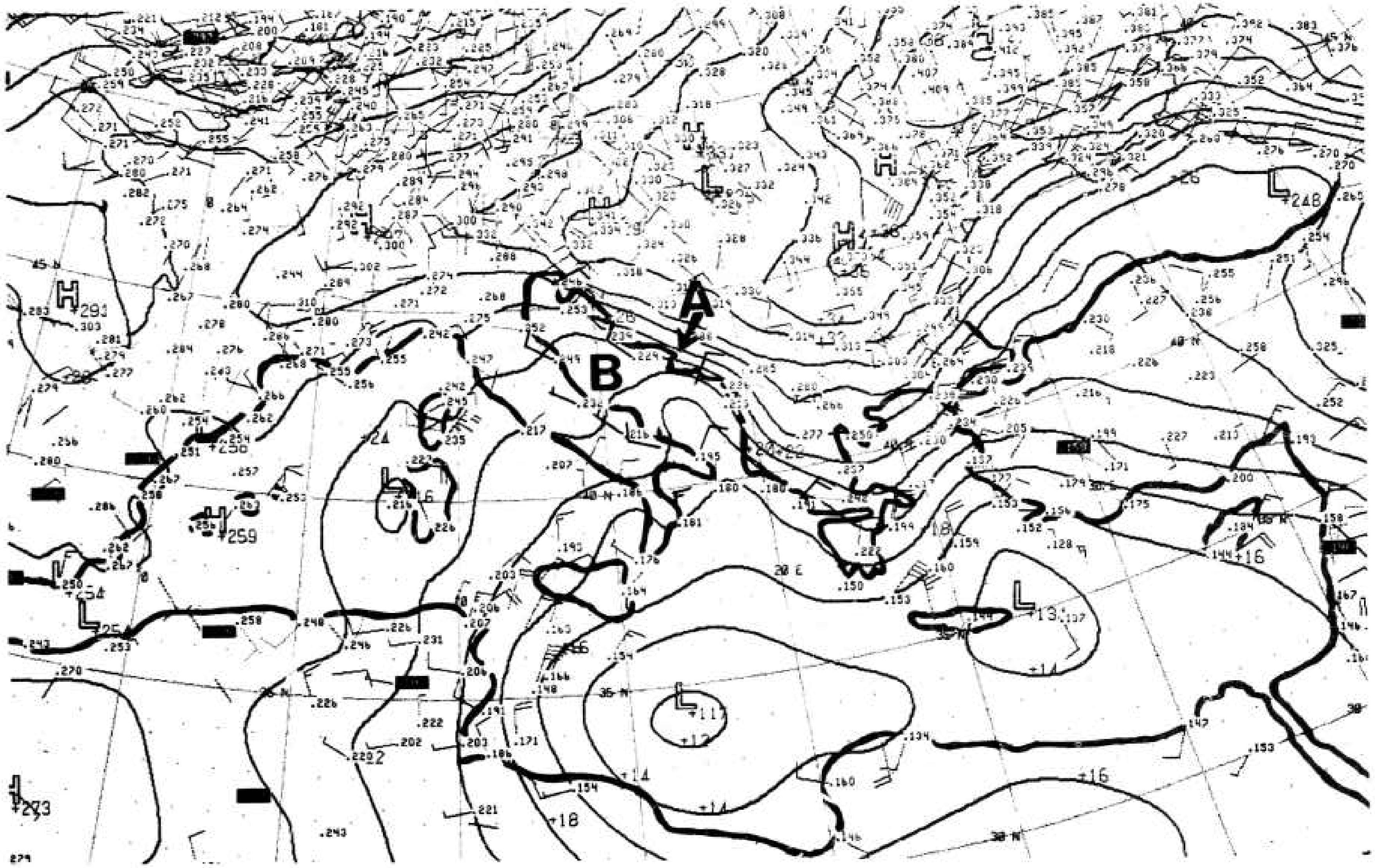

Figure 6a. FIB/SLP-MED analysis, 0600 GMT, 26 January 1973.

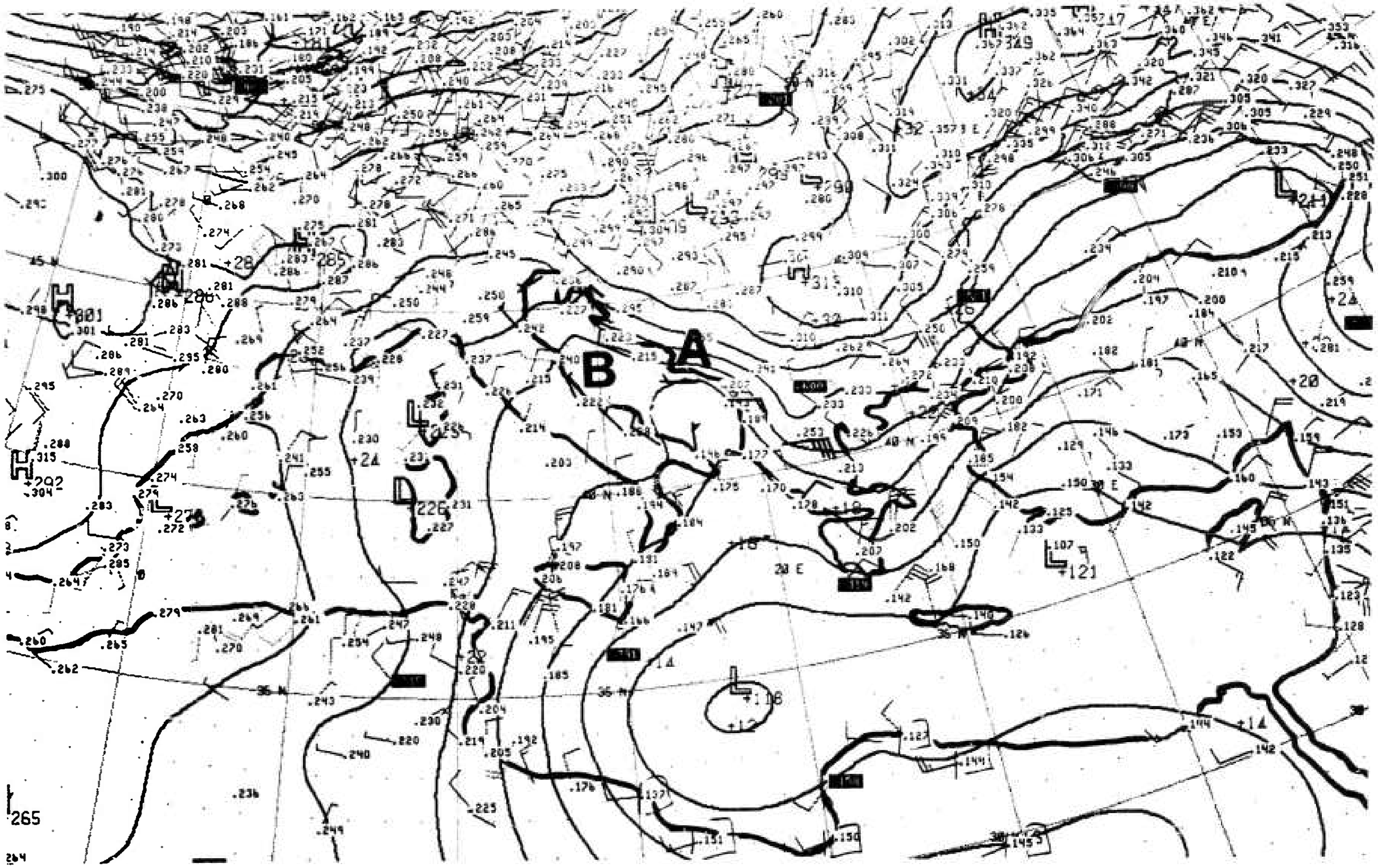

Figure 6b. FIB/SLP-MED analysis, 1200 GMT, 26 January 1973.

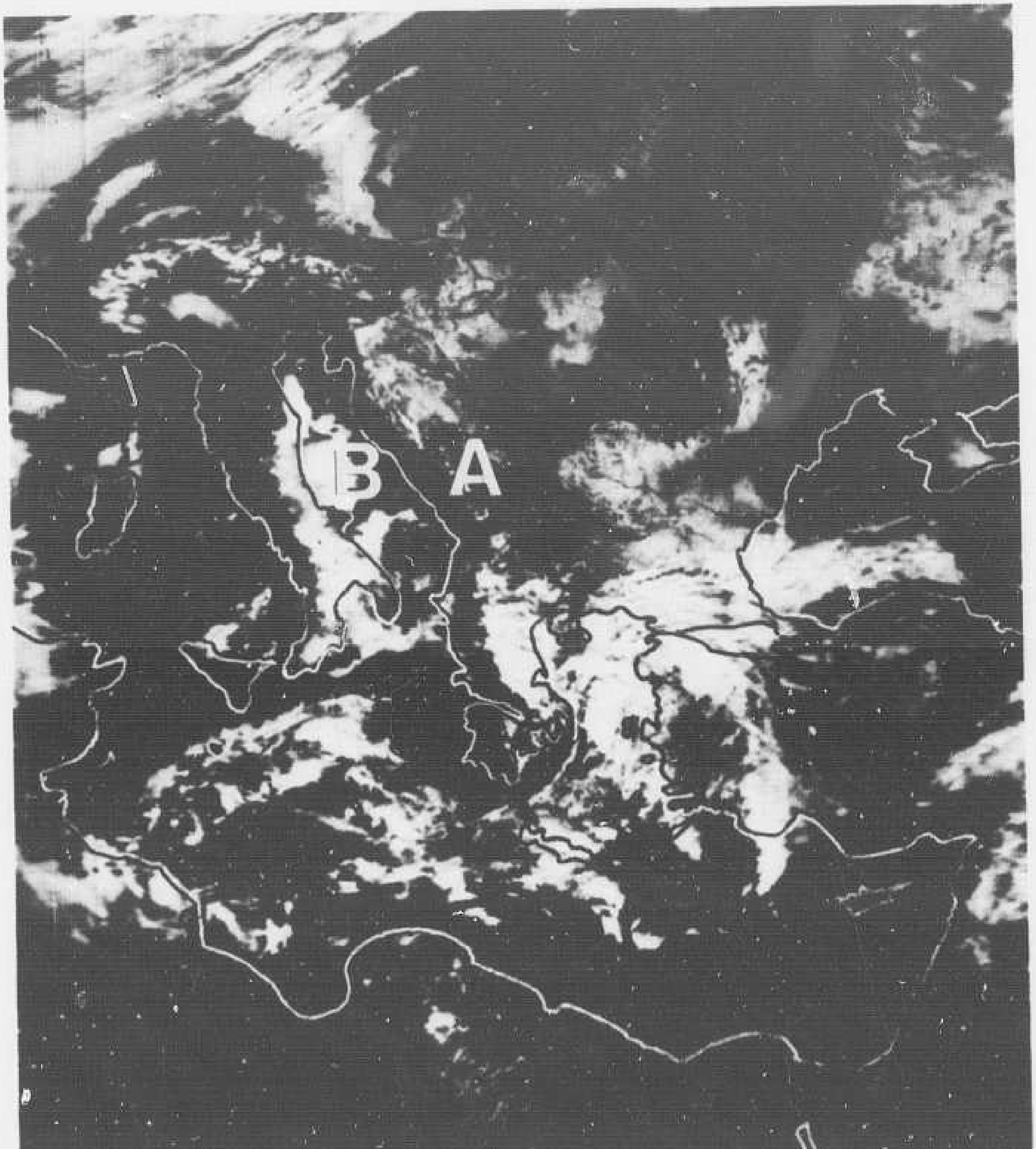

Figure 7a. DMSP high-resolution visual, 1009 GMT, 26 January 1973.

Figure 7b. DMSP IR, 1009 GMT, 26 January 1973.

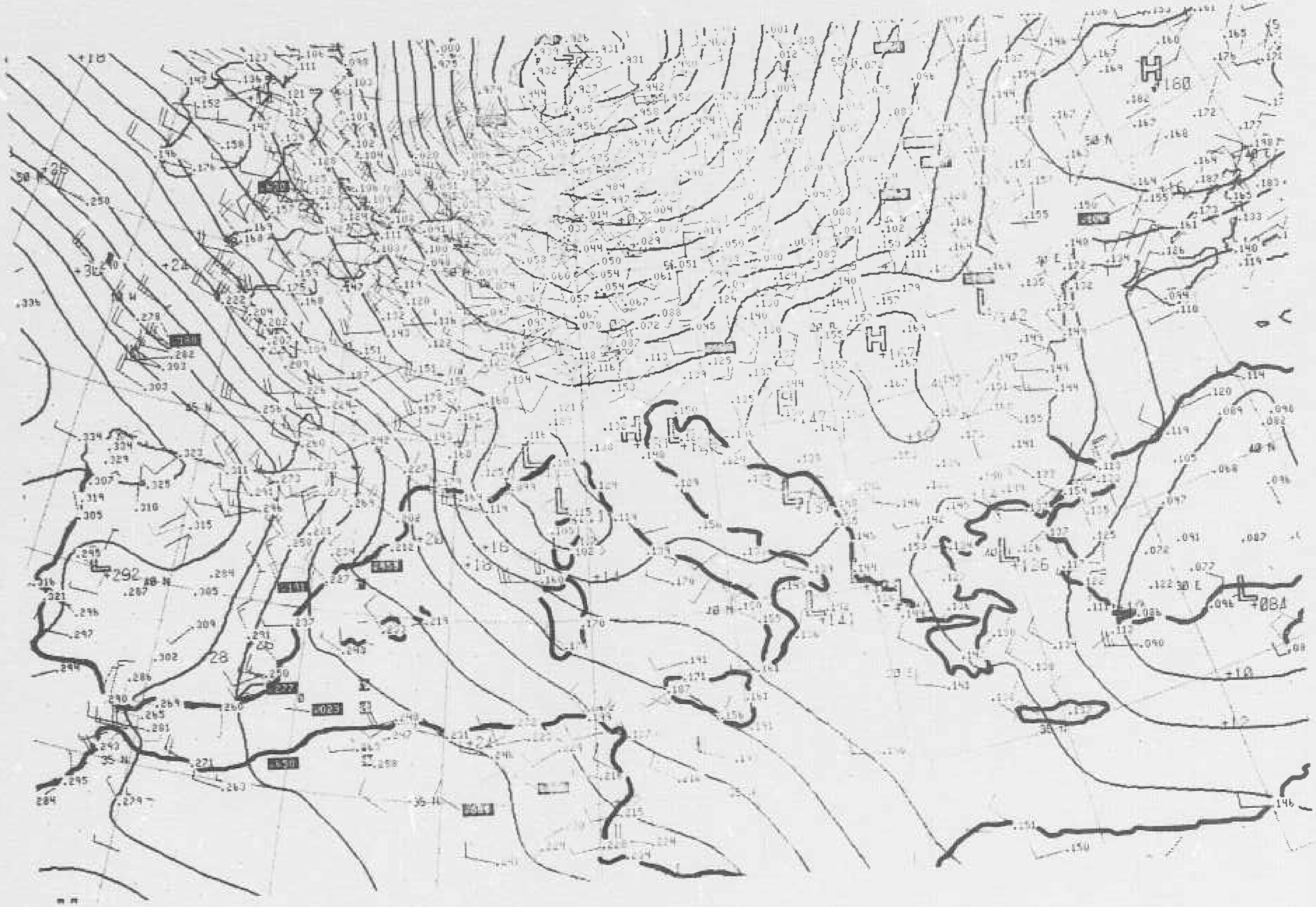

Figure 8. FIB/SLP-MED analysis, 1200 GMT, 27 January 1973.

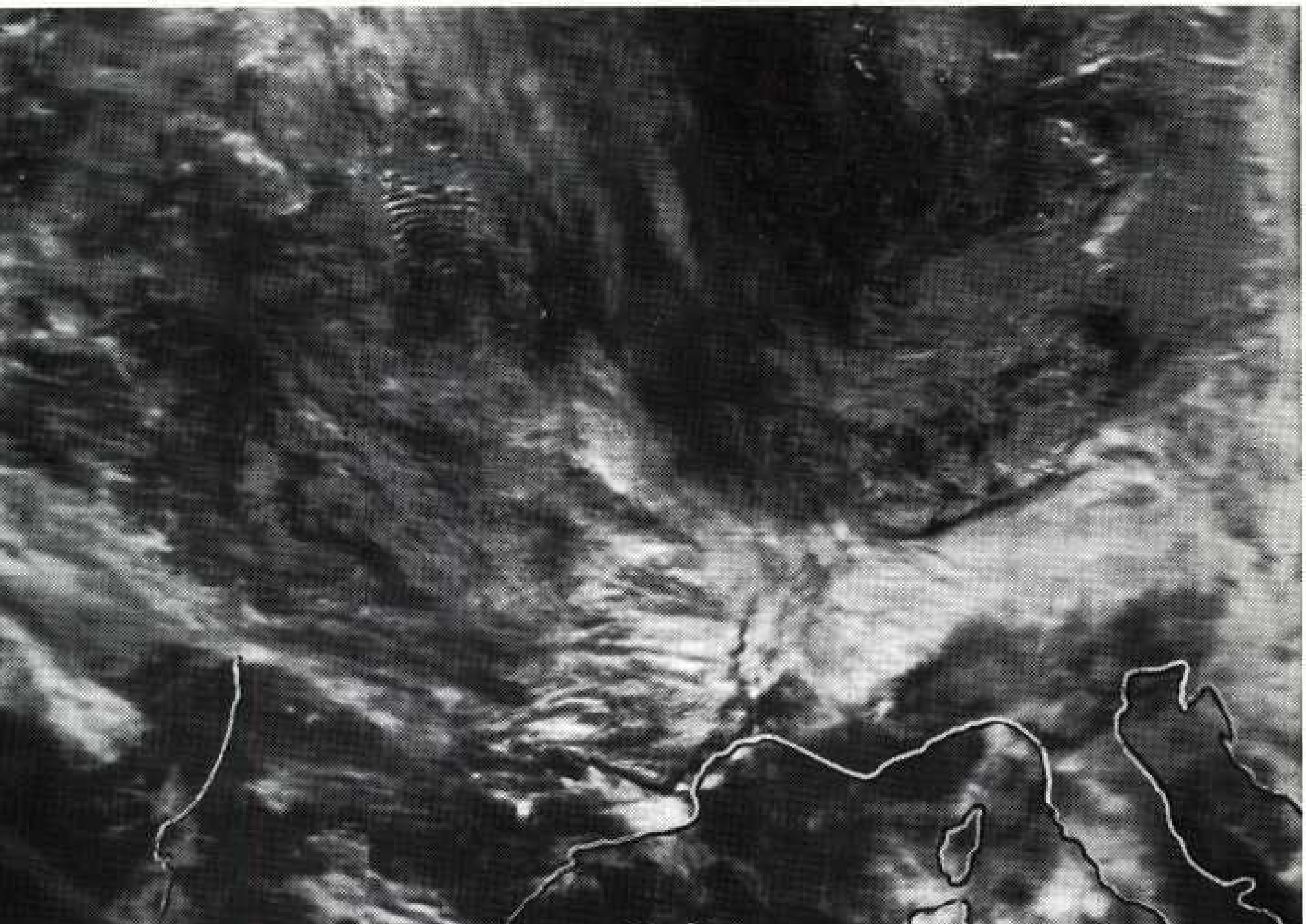

Figure 9a. DMSP high-resolution visual, 1136 GMT, 27 January 1973.

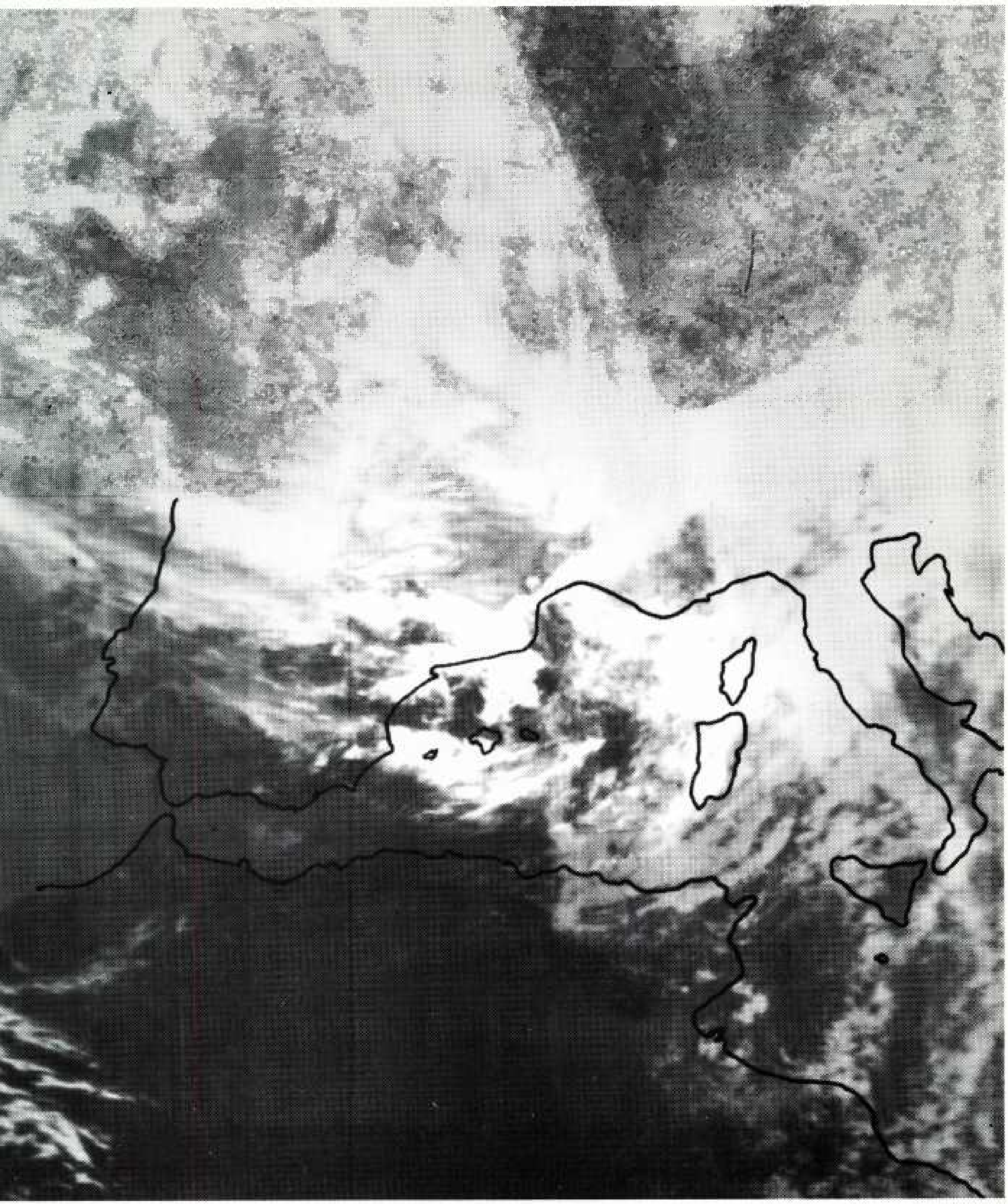

Figure 9b. DMSP IR, 1136 GMT, 27 January 1973.

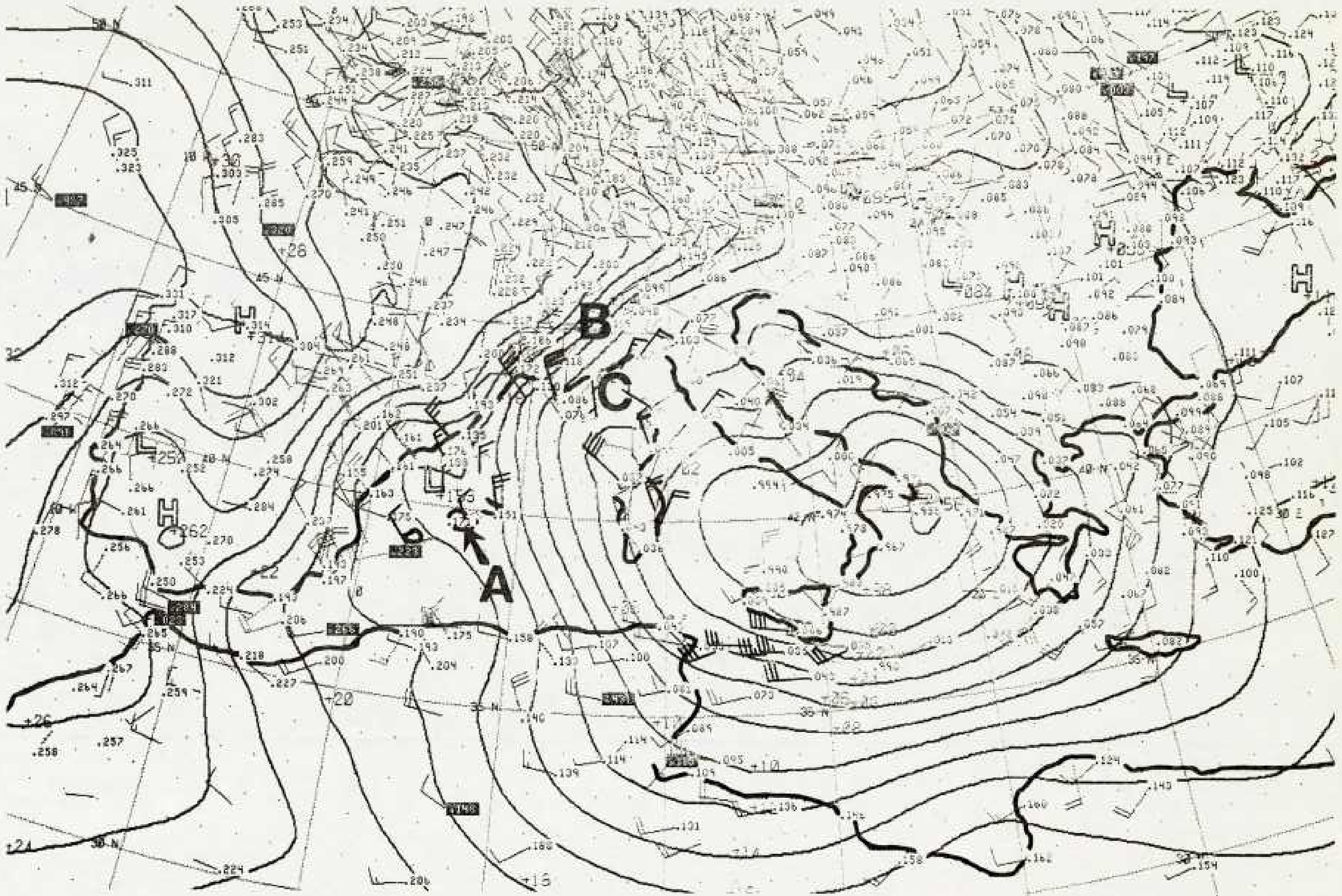

Figure 10. FIB/SLP-MED analysis, 1200 GMT, 28 January 1973.

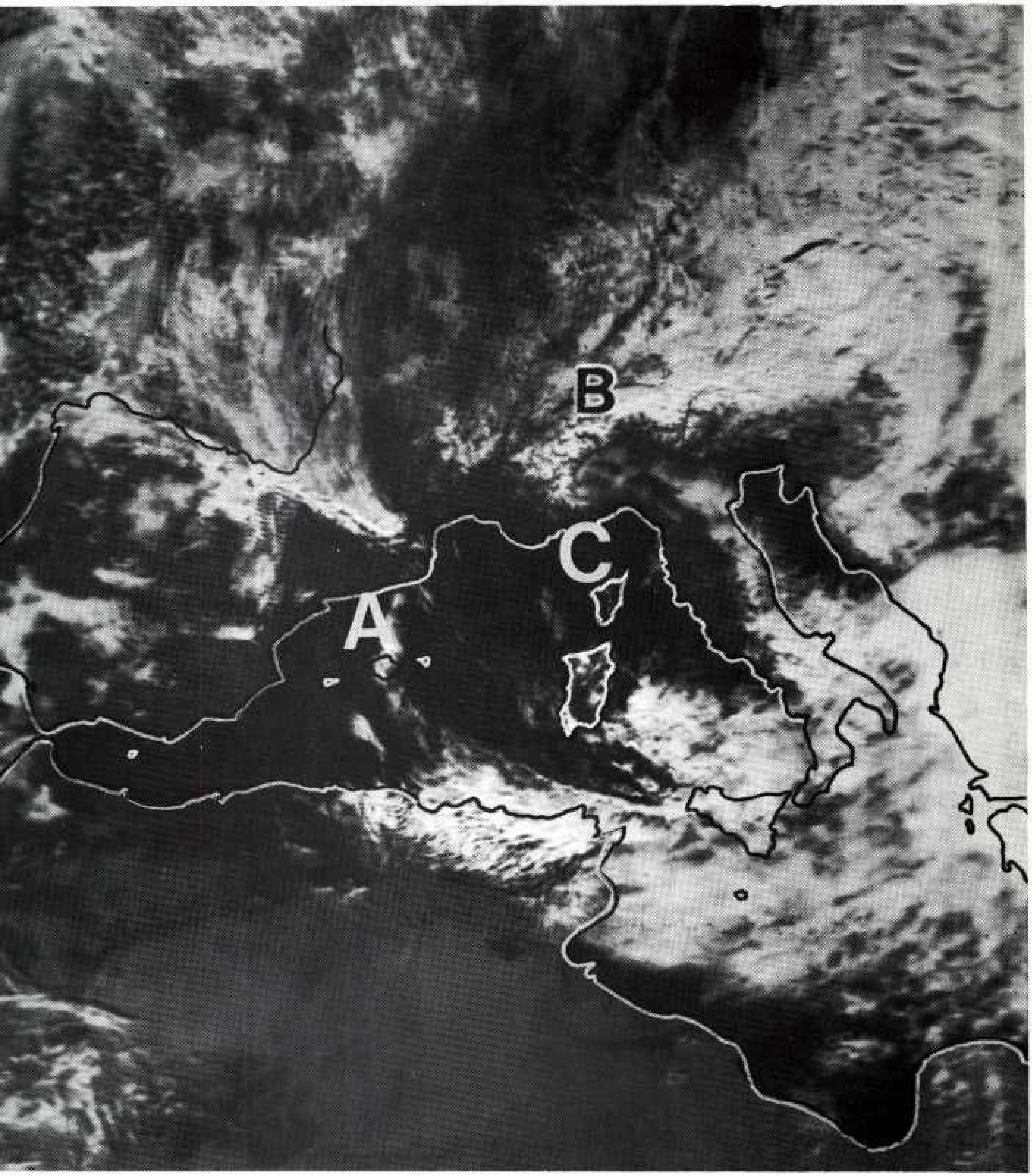

Figure 11a. DMSP high-resolution visual, 1122 GMT, 28 January 1973.

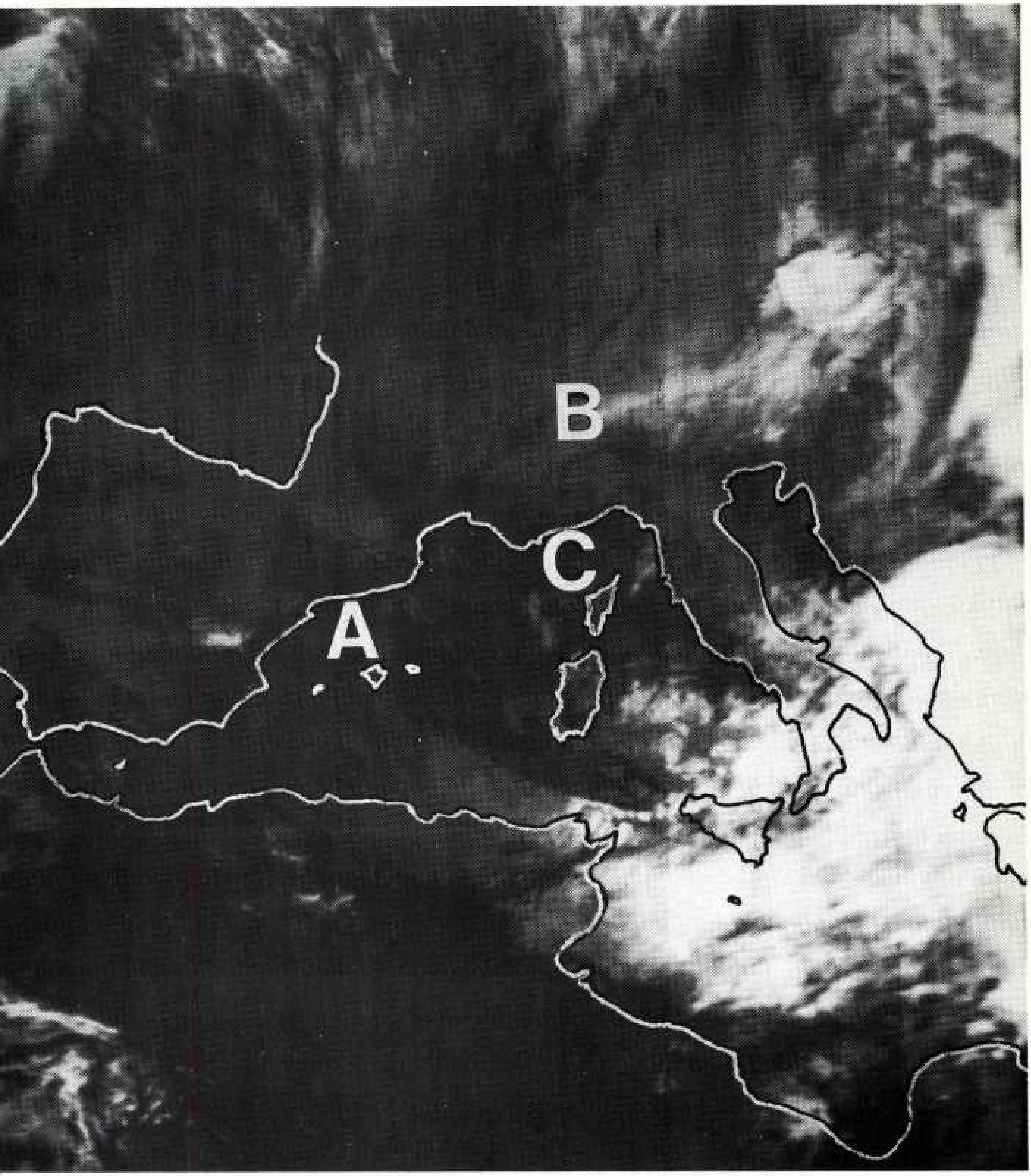

Figure 11b. DMSP IR, 1122 GMT, 28 January 1973.

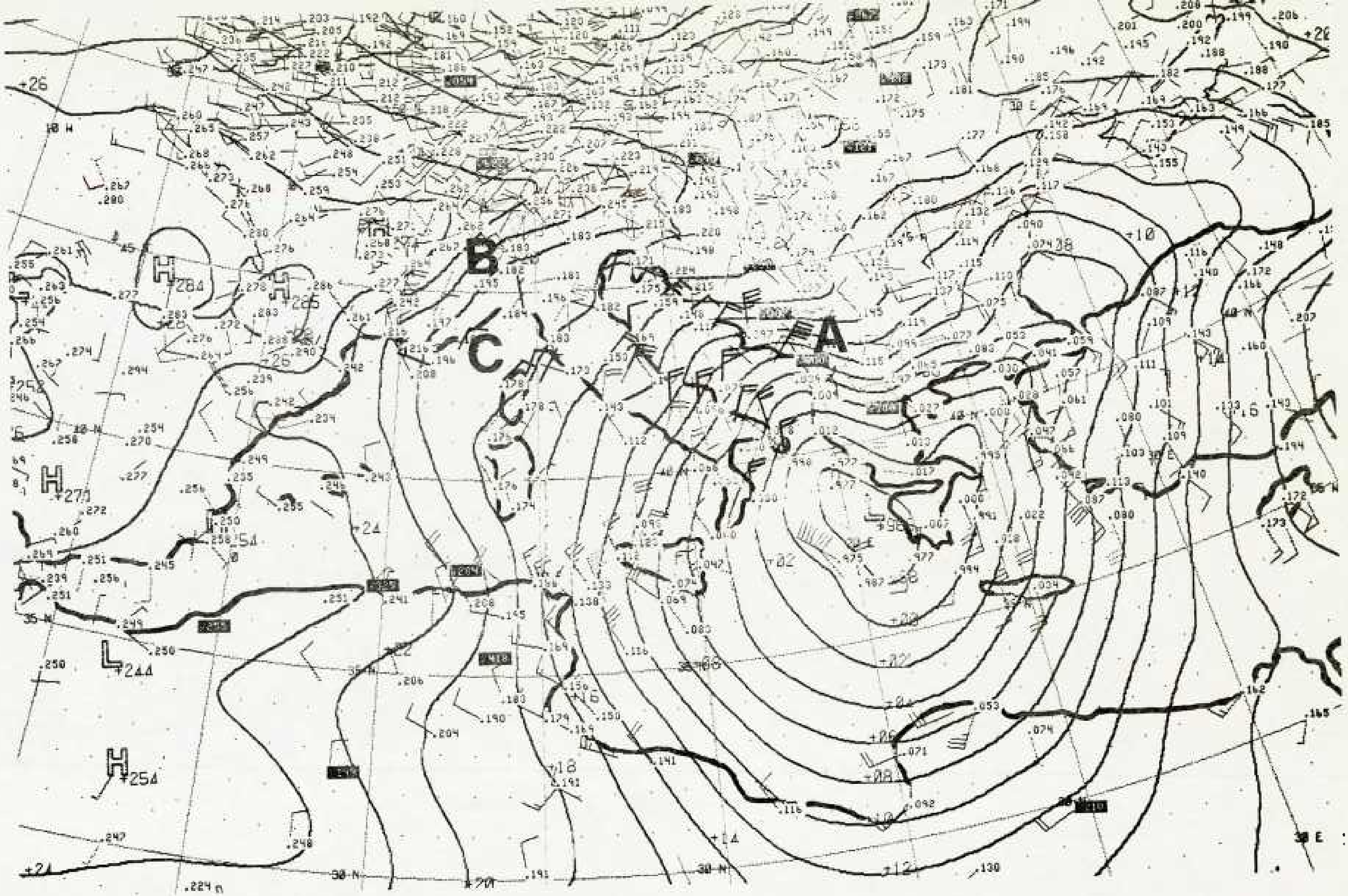

Figure 12. FIB/SLP-MED analysis, 1200 GMT, 29 January 1973.

Figure 13a. DMSP high-resolution visual, 1107 GMT, 29 January 1973.

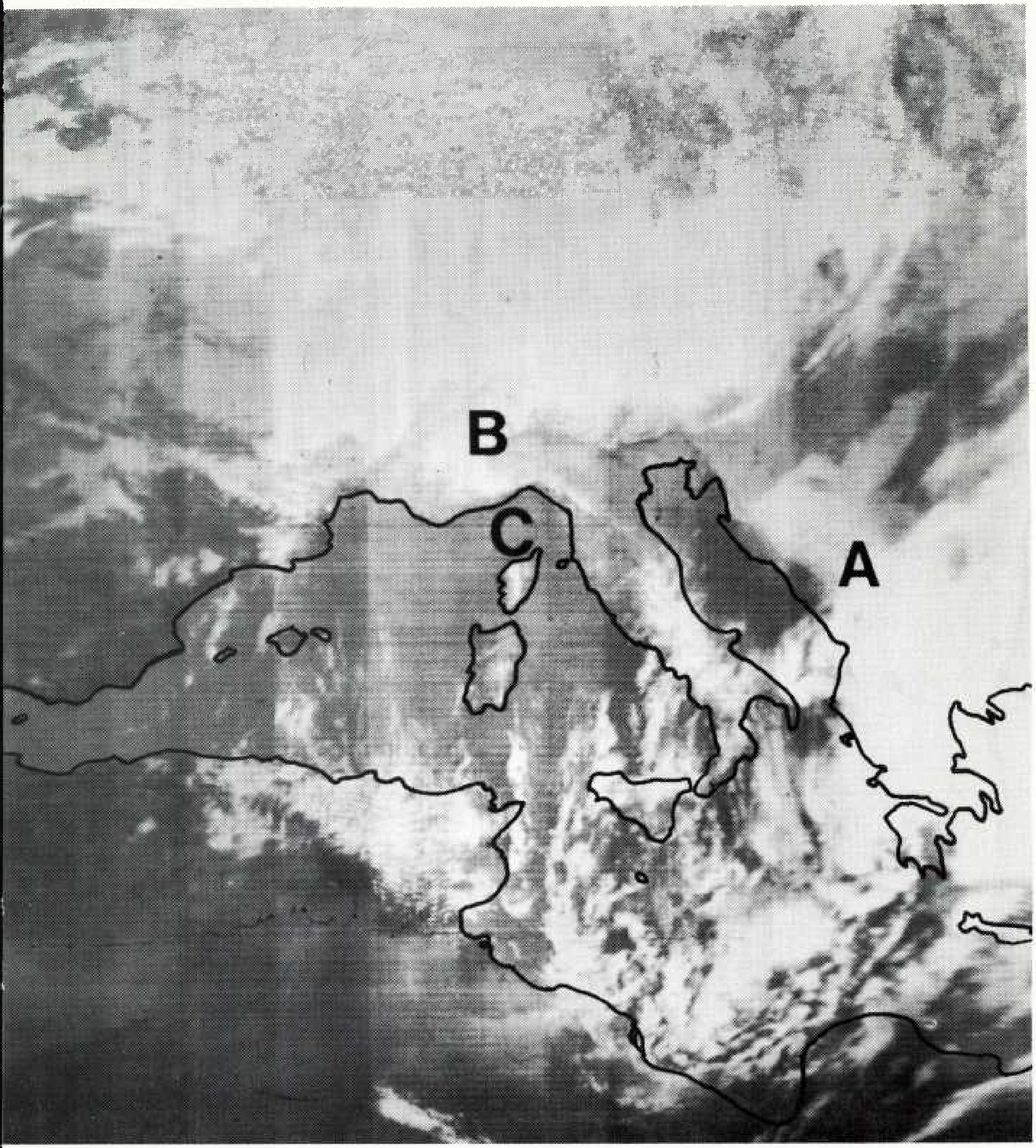

Figure 13b. DMSP IR, 1107 GMT, 29 January 1973.

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